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Blue Mountain Lake Logan and Yell Counties Arkansas

National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

Jan 77

PB 268 314

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Report
on
Blue Mountain Lake
Logan and Yell Counties
Arkansas
EPA Region VI
Working Paper No. 482

With the cooperation of the
Arkansas Department of Pollution
Control and Ecology
and the
Arkansas National Guard
January, 1977

REPORT ON BLUE MOUNTAIN LAKE

LOGAN AND YELL COUNTIES, ARKANSAS

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 482

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

January 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Arkansas Department of Pollution Control and Ecology for professional involvement, to the Arkansas National Guard for conducting the tributary sampling phase of the Survey, and to those Arkansas wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Water Division of the Arkansas Department of Pollution Control and Ecology provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper series.

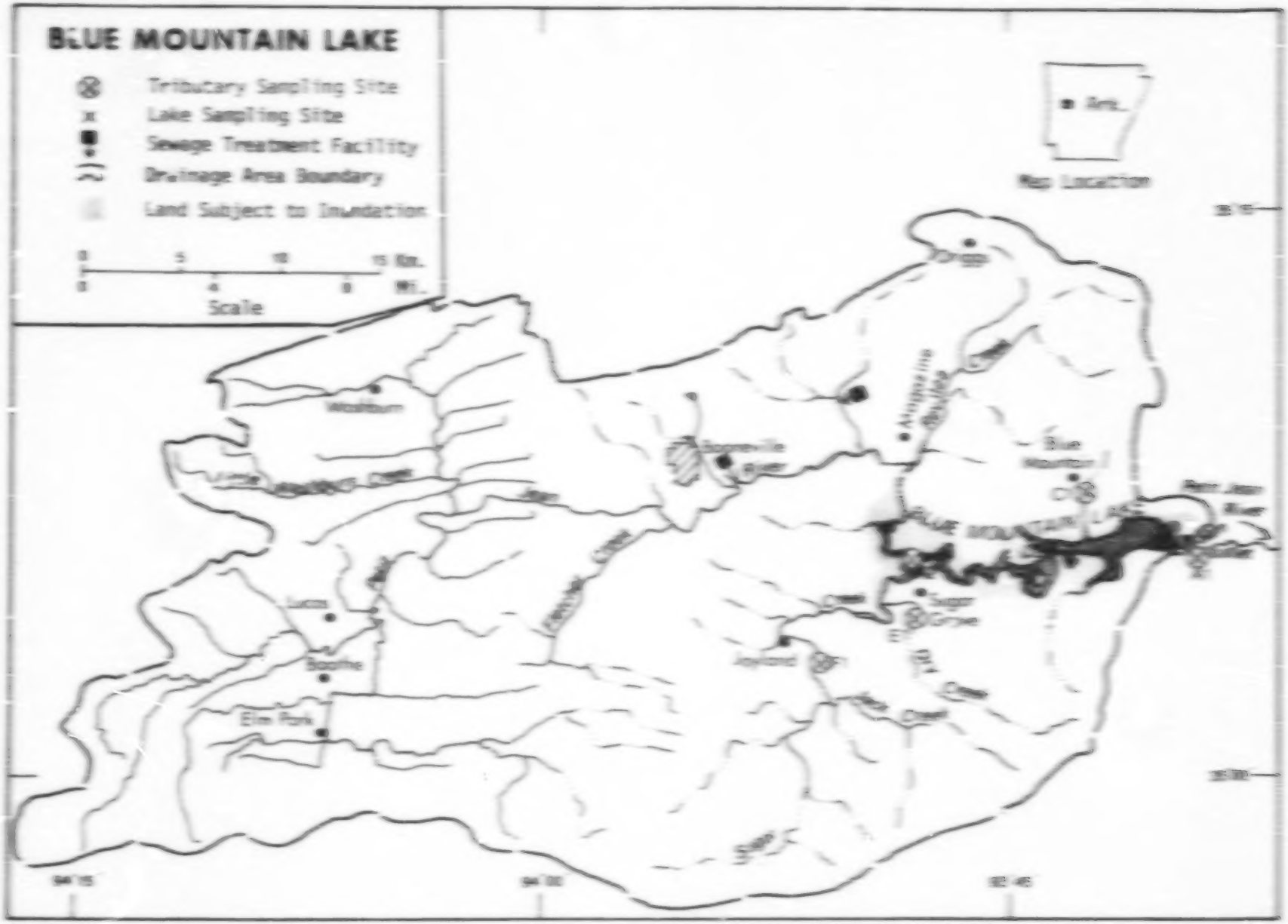
Major General Thomas C. Armstrong, the Adjutant General of Arkansas, and Project Officer Colonel Lavaun M. James, who directed the volunteer efforts of the Arkansas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF ARKANSAS

LAKE NAME	COUNTY
Beaver	Benton, Carroll, Washington
Blackfish	Crittenden, St. Francis
Blue Mountain	Logan, Yell
Bull Shoals	Baxter, Boone, Marion (Taney, Ozark in MO)
Catherine	Garland, Hot Spring
Chicot	Chicot
DeGray	Clark, Hot Spring
Erling	Lafayette
Grand	Chicot
Greer's Ferry	Van Buren, Cleburne
Hamilton	Garland
Millwood	Hempstead, Howard, Little River, Sevier
Nimrod	Perry, Yell
Norfork	Baxter, Fulton (Ozark in MO)
Ouachita	Garland, Montgomery
Table Rock	Boone, Carroll (Barry, Taney in MO)


BLUE MOUNTAIN LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
Land Subject to Inundation
Scale
Ark.
Map Location
Hackett
Lavaca Creek
Lucas
Booneville
Elm Fork
Blue Mountain
BLUE MOUNTAIN LAKE
Petit Jean River
Upper Entrance
Spillway
Holland
Cove Creek
Mill Creek

REPORT ON BLUE MOUNTAIN LAKE, ARKANSAS

STORET NO. 0503

I. CONCLUSIONS

A. Trophic Condition:*

On the basis of field observations and Survey data, Blue Mountain Lake is considered eutrophic, i.e., nutrient rich and productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a values ranged from 5.3 µg/l in the spring to 14.1 µg/l in the fall, with a mean of 9.0 µg/l. Potentials for primary production as measured by algal assay control yields were moderate to high. Of the 16 Arkansas lakes sampled in 1974, 3 had higher median total phosphorus values, 4 had higher median orthophosphorus levels, and 7 had higher median inorganic nitrogen values than Blue Mountain Lake.

Dissolved oxygen levels were sharply depressed at Station 01 below 4.6 meters (15 feet) during summer sampling. Survey limnologists reported no other problem conditions in the lake. However, other studies (Arkansas Department of Pollution Control and Ecology, 1972) indicate that the shallow upper end of the lake may be trapping nutrients, resulting in heavy algal and macrophyte growth.

*See Appendix E

B. Rate-Limiting Nutrient:

Algal assay results indicate primary limitation by phosphorus in Blue Mountain Lake. Mean inorganic nitrogen to orthophosphorus (N/P) ratios for the lake were 16/1 and 26/1 in the summer and fall, respectively, indicating phosphorus limitation, and 9/1 in the spring, suggesting nitrogen limitation.

C. Nutrient Controllability:

1. Point sources -

During the sampling year, point sources were estimated to have contributed 30.0% of the total phosphorus load to Blue Mountain Lake. The city of Booneville contributed 28.3% of this load.

The total annual phosphorus loading of 1.44 $g/m^2/yr$ is slightly greater than Vollenweider's (1975) proposed eutrophic loading rate for lakes with such volume and retention time. However, loading calculations for the lake yield a large net export of phosphorus. This apparent phosphorus export could be attributed to undetected discharges reaching the lake from unmeasured industrial or municipal sources, to underestimation of the phosphorus load from septic tanks or to insufficient tributary sampling to determine an accurate nutrient budget for the lake. Although additional sampling is needed before definitive recommendations for the lake can be proposed, reduction of phosphorus loading from the Booneville plant to

the greatest practicable extent should aid in improving water quality in Blue Mountain Lake.

2. Nonpoint sources -

The mean annual phosphorus load from nonpoint sources was about 70.0% of the total reaching the lake measured tributaries accounted for over 61.0% of the total phosphorus load and the unmaged drainage areas were estimated to have contributed 5.4%.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry was provided by the Arkansas Department of Pollution Control and Ecology; tributary flow data were provided by the Arkansas District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

Tributary D-1, Cedar Creek, does not impact Blue Mountain Lake, but flows into the Petit Jean River below Blue Mountain Dam. For this reason, drainage area, flow, and nutrient loading values for D-1 have not been included with the other tributaries flowing into Blue Mountain Lake.

A. Lake Morphometry:

1. Surface area: 11.74 km^2.
2. Mean depth: 2.6 meters.
3. Maximum depth: 12.8 meters.
4. Volume: 30.837 x 10^6 m^3.
5. Mean hydraulic retention time: 25 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area(km^2)	Mean flow (m^3/sec)
A-2 Petit Jean River	890.7	10.60
E-1 Dry Creek	33.7	0.39
F-1 Sugar Creek	151.3	1.77
Minor tributaries and immediate drainage -	139.8	1.77
Totals	1,223.5	14.61
2. Outlet - A-1 Petit Jean River	1,263.9	14.01

C. Precipitation:

1. Year of sampling: 114.9 cm.
2. Mean annual: 114.2 cm.

III. LAKE WATER QUALITY SUMMARY

Blue Mountain Lake was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from one or more depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 10.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 8.5 meters at Station 01 and 2.7 meters at Station 02. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/28/74	1. Melosira	2,302
	2. Chroomonas	1,069
	3. Dactylococcopsis	701
	4. Cryptomonas	247
	5. Asterionella	164
	Other genera	288
	Total	4,861
06/06/74	1. Melosira	3,828
	2. Euglena	58
	3. Nitzschia	58
	4. Anabaena	29
	5. Crucigenia	29
	Other genera	29
	Total	4,031
10/10/74	1. Melosira	1,830
	2. Stephanodiscus	790
	3. Chlamydomonas	333
	4. Dactylococcopsis	166
	5. Oscillatoria	166
	Other genera	374
	Total	3,659

F. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/28/74	01	5.3
	02	7.8
06/06/74	01	7.9
	02	10.6
10/18/74	01	9.4
	02	14.1

G. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. 03/28/74

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.015	0.153	1.9
0.05 P	0.065	0.153	2.1
0.05 P + 1.0 N	0.065	1.153	25.5
1.00 N	0.015	1.153	2.1

b. 10/18/74

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.010	0.092	0.8
0.05 P	0.060	0.092	5.0
0.05 P + 1.00 N	0.060	1.092	16.4
1.00 N	0.010	1.092	0.6

F. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential for primary production in Blue Mountain Lake was high during spring sampling and moderately high during fall. In both assays, substantial growth responses to the addition of phosphorus alone, as well as the lack of response to the addition of nitrogen indicate phosphorus limitation. Maximum growth yields were achieved with the simultaneous addition of both nutrients.

Mean N/P ratios in the lake data were 16/1 and 26/1 for the summer and fall sampling periods, indicating primary limitation by phosphorus, but 9/1 in the spring, suggesting nitrogen limitation at that time (an N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Arkansas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of March and April when two samples were collected. Sampling was begun in June 1975, and was completed in May 1976.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Arkansas District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in kg/km^2/yr, in Dry Creek and Sugar Creek at Stations E-1 and F-1, and multiplying the means by the ZZ area in km^2.

The operator of the Booneville wastewater treatment plant provided monthly effluent samples and corresponding flow data. Nutrient loads for the Arkansas Children's Colony wastewater treatment plant were estimated at 1.134 kg P and 3.401 kg N/Capita/yr.

A. Waste Sources:

1. Known municipal -

Name	Population Served	Treatment	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Booneville	4,263	Activated sludge	1.597	Petit Jean River
Arkansas Children's Colony*	255*	Trickling filter	0.965**	Petit Jean River

2. Known industrial - None

*Arkansas Department of Pollution Control and Ecology, 1975.
**Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source		kg P/yr	% of total
a.	Tributaries (nonpoint load) -		
	A-2 Petit Jean River	9,425	55.9
	E-1 Dry Creek	250	1.6
	F-1 Sugar Creek	990	5.9
b.	Minor tributaries and immediate drainage (nonpoint load) -	910	5.4
c.	Known municipal STP's -		
	Booneville	4,775	28.3
	Arkansas Children's Colony	290	1.7
d.	Septic tanks* -	5	<0.1
e.	Known industrial - None		
f.	Direct precipitation** -	205	1.2
	Totals	16,850	100.0
2.	Output - A-1 Petit Jean River	31,255	
3.	Net annual P export*** -	14,405	

*Estimate based on 10 lakeside residences and 4 parks.
**Estimated (see NES Working Paper No. 175).
***Export probably due to unknown sources and/or sampling error.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of Total
a. Tributaries (nonpoint load) -		
A-2 Petit Jean River	344,485	81.1
E-1 Dry Creek	7,180	1.7
F-1 Sugar Creek	27,865	6.6
b. Minor tributaries and immediate drainage (nonpoint load) -	27,750	6.5
c. Known municipal STP's -		
Booneville	3,430	0.8
Arkansas Children's Colony	865	0.2
d. Septic tanks* -	250	0.1
e. Known industrial - None		
f. Direct precipitation** -	12,675	3.0
Totals	424,500	100.0
2. Output - A-1 Petit Jean River	343,495	
3. Net annual N accumulation -	81,005	

*Estimate based on 10 lakeside residences and 4 parks.
**Estimated (see NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Petit Jean River	10	303
Dry Creek	7	213
Sugar Creek	6	184

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
C-1 Unnamed Stream	0.029	0.644
D-1 Cedar Creek	0.028	0.913

Nutrient levels for tributary C-1, Unnamed Stream, are in line with the nutrient levels found in the measured unimpacted tributaries entering the lake. Although Cedar Creek, tributary D-1, is outside the Blue Mountain Lake watershed, it was sampled as a special Land Use Study site. Phosphorus levels for that tributary are comparable to the other streams entering the lake, however, nitrogen values are somewhat higher.

f. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his eutrophic loading is that at which the receiving waters would become eutrophic or remain eutrophic; his oligotrophic loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between eutrophic and oligotrophic.

Note that Vollenweider's model may not apply to lakes with short hydraulic retention times or in which light penetration is severely restricted by high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Blue Mountain Lake	1.44
Vollenweider's eutrophic loading	1.17
Vollenweider's oligotrophic loading	0.59

V. LITERATURE REVIEWED

Arkansas Department of Pollution Control and Ecology. 1972. Pollution Control Survey of Arkansas River Basins, August - October, 1972. Little Rock, Arkansas.

Arkansas Department of Pollution Control and Ecology. 1975. Section 303(e) Basin Plan for Arkansas River Basin, Oklahoma State Line to Mouth. Little Rock, Arkansas.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.393) = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

[illegible] FLOW INFORMATION FOR [illegible] [illegible]

LAND USE DATA FLOW MULTIPLICATION LAPSE

TOTAL DRAINAGE AREA OF LAPSE(S) = 1263.9

SUB-DRAINAGE	AREA (SQ MI)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
[illegible]	1263.9	34.35	25.76	24.43	32.79	27.72	19.62	9.52	9.12	3.74	2.49	8.17	14.68	14.91
[illegible]	698.7	15.47	28.33	33.53	39.42	28.49	4.43	3.13	1.76	1.93	1.76	0.23	9.17	11.99
[illegible]	24.7	0.486	0.825	0.617	0.631	0.643	0.753	0.691	0.854	0.854	0.854	0.193	0.896	0.721
[illegible]	33.7	0.568	0.734	0.616	0.742	0.753	0.174	0.119	0.865	0.871	0.865	0.227	0.334	0.389
[illegible]	151.3	2.64	3.37	3.34	3.37	3.43	0.47	0.58	0.29	0.32	0.29	1.63	1.52	1.77
[illegible]	151.3	2.65	3.37	3.34	3.37	3.43	0.42	0.58	0.29	0.32	0.29	1.83	1.52	1.77

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 1263.9 TOTAL FLOW IN = 146.13

SUM OF SUB-DRAINAGE AREAS = 1263.9 TOTAL FLOW OUT = 178.29

[illegible] MONTHLY FLOWS AND DAILY FLOWS/CMS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
[illegible]	6	74	29,366	22	42,459				
	7	74	1,501	28	8,709				
	8	74	8,709	16	8,709				
	9	74	7,447	22	14,539				
	10	74	8,698	19	8,348				
	11	74	5,919	23	35,396				
	12	74	32,844	23	41,629				
	1	75	38,958	18	33,980				
	2	75	43,523	22	44,174				
	3	75	29,298	9	9,429	23	62,297		
	4	75	58,134	5	67,468	19	34,756		
	5	75	41,654	17	58,659				
[illegible]	6	74	21,219	22	3,548				
	7	74	6,323	28	8.6				
	8	74	6,363	16	6,883				
	9	74	4,219	22	3,548				
	10	74	1,849	19	8,241				
	11	74	38,831	23	5,897				
	12	74	36,477	23	3,673				
	1	75	14,243	19	7,362				
	2	75	31,446	22	44,457				
	3	75	47,263	9	18,462	23	104,938		
	4	75	34,817	5	9,911	19	3,398		
	5	75	28,971	17	6,211				

APPENDIX C

PHYSICAL AND CHEMICAL DATA

[illegible]

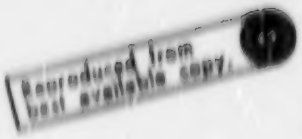
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TEMP	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TU	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	15	45	[illegible]	15.2	9.4	32		7.19	24	0.873	0.401	0.698	0.424
[illegible]	15	45	[illegible]	15.4	9.4	32	45	6.71	23	1.126	0.485	0.868	0.812
	15	45	[illegible]	15.4	9.4		47	6.66	24	1.125	0.588	0.846	0.811
	15	45	[illegible]	15.4	9.4		48	6.67	24	1.128	0.588	0.858	0.811
	15	45	[illegible]	15.4	9.4		48	6.67	28	1.842	0.481	0.846	0.384
[illegible]	15	45	[illegible]	17.4	9.9	32	44	6.64	19	0.848	0.488	0.858	0.884
	15	45	[illegible]	18.4	9.9								

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]
TEMP	OF		[illegible]	[illegible]	[illegible]
TU	DAY	FEET	[illegible]	[illegible]	[illegible]
[illegible]	15	45	[illegible]	7.2	
[illegible]	15	45	[illegible]	10.8	
	15	45	[illegible]		
	15	45	[illegible]		
[illegible]	15	45	[illegible]	14.1	
	15	45	[illegible]		3.8

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA



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APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF ARKANSAS

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